Claims

1. An electronic circuit sensitivity analysis method for analyzing sensitivity of an electronic circuit model as represented by electronic circuit model data, comprising:

conducting a first computer simulation of the electronic circuit model and receiving results of the first simulation;

identifying a nonlinear circuit element in the electronic circuit model and representing a nonlinear effect of the nonlinear circuit element by applying a corresponding voltage source to the electronic circuit model;

generating an adjoint of the electronic circuit model based upon the results of the first simulation, including mapping the corresponding voltage source into a current source in the adjoint;

conducting a second simulation of the adjoint of the electronic circuit model and receiving results of the second simulation; and

conducting a circuit sensitivity analysis of the electronic circuit model based upon the results of the simulations of the electronic circuit model and the adjoint to it.

2. The method of claim 1 wherein:

plural nonlinear circuit elements are identified in the electronic circuit model and nonlinear effects of the plural nonlinear circuit elements are represented by applying plural corresponding voltage sources to the electronic circuit model; and

an adjoint of the electronic circuit model is generated based upon the results of the first simulation, including mapping the plural corresponding voltage sources into current sources in the adjoint.

3. The method of claim 1 in which the current source in the adjoint to which the corresponding voltage source is mapped is a current-controlled current source.

4. The method of claim 1 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear admittance.

5. The method of claim 4 in which the current source $\hat{I}_+$ in the adjoint to which the corresponding voltage source is mapped is represented by

$$\hat{I}_+ = \frac{\partial y}{\partial v}\frac{I_0}{y_0^2}\hat{I}$$

where y is admittance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, y_0 is a nominal, operating point admittance of the nonlinear circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.

6. The method of claim 1 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear impedance.

7. The method of claim 6 in which the current source $\hat{I}_+$ in the adjoint to which the corresponding voltage source is mapped is represented by

$$\hat{I}_+ = -\frac{\partial R}{\partial v}I_0\hat{I}$$

where R is impedance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.

8. In an electronic circuit sensitivity analysis method for analyzing sensitivity of an electronic circuit model as represented by electronic circuit model data and employing an adjoint of the electronic circuit model, the improvement comprising:

identifying a nonlinear circuit element in the electronic circuit model and representing a nonlinear effect of the nonlinear circuit element by applying a

corresponding voltage source to the electronic circuit model; and

generating the adjoint of the electronic circuit model with a mapping of the corresponding voltage source into a current source in the adjoint.

9. In an electronic circuit sensitivity analysis method for analyzing sensitivity of an electronic circuit model as represented by electronic circuit model data and employing an adjoint of the electronic circuit model, the improvement comprising:

identifying in the electronic circuit model a nonlinear circuit element having a nonlinear effect; and

generating the adjoint of the electronic circuit model with a current source representing the nonlinear effect of the nonlinear circuit element.

10. The method of claim 9 wherein:

plural nonlinear circuit elements are identified in the electronic circuit model and have nonlinear effects; and

the adjoint of the electronic circuit model is generated plural current sources representing the nonlinear effects of the plural nonlinear circuit elements.

11. The method of claim 9 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear admittance.

12. The method of claim 11 in which the current source $\hat{I}_+$ in the adjoint is represented by

$$\hat{I}_+ = \frac{\partial y}{\partial v}\frac{I_0}{y_0^2}\hat{I}$$

where y is admittance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, y_0 is a nominal, operating point admittance of the nonlinear

circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.

13. The method of claim 9 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear impedance.

14. The method of claim 13 in which the current source $\hat{I}_+$ in the adjoint is represented by

$$\hat{I}_+ = -\frac{\partial R}{\partial v} I_0 \hat{I}$$

where R is impedance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.

15. In an computer readable medium, electronic circuit sensitivity analysis software for analyzing sensitivity of an electronic circuit model as represented by electronic circuit model data and employing an adjoint of the electronic circuit model, the improvement comprising:

software for identifying a nonlinear circuit element in the electronic circuit model and representing a nonlinear effect of the nonlinear circuit element by applying a corresponding voltage source to the electronic circuit model; and

software for generating the adjoint of the electronic circuit model with a mapping of the corresponding voltage source into a current source in the adjoint.

16. In a computer readable medium, electronic circuit sensitivity analysis software for analyzing sensitivity of an electronic circuit model as represented by electronic circuit model data and employing an adjoint of the electronic circuit model, the improvement comprising:

software for identifying in the electronic circuit model a nonlinear circuit element having a nonlinear effect; and

software for generating the adjoint of the electronic circuit model with a current source representing the nonlinear effect of the nonlinear circuit element.

17. The medium of claim 16 wherein:

plural nonlinear circuit elements are identified in the electronic circuit model and have nonlinear effects; and

the adjoint of the electronic circuit model is generated plural current sources representing the nonlinear effects of the plural nonlinear circuit elements.

18. The medium of claim 16 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear admittance.

19. The medium of claim 18 in which the current source $\hat{I}_+$ in the adjoint is represented by

$$\hat{I}_+ = \frac{\partial y}{\partial v}\frac{I_0}{y_0^2}\hat{I}$$

where y is admittance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, y_0 is a nominal, operating point admittance of the nonlinear circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.

20. The medium of claim 16 in which the nonlinear effect of the nonlinear circuit element is characterized by a nonlinear impedance.

21. The medium of claim 20 in which the current source $\hat{I}_+$ in the adjoint is represented by

$$\hat{I}_{+} = -\frac{\partial R}{\partial v} I_0 \hat{I}$$

where R is impedance, v is voltage, I_0 is a nominal, operating point current through the nonlinear circuit element, and $\hat{I}$ is the adjoint current through the nonlinear circuit element.